ELASTICITY MEASURING DEVICE FOR BIOLOGICAL TISSUE

BACKGROUND OF THE INVENTION

1. Field of the Invention

5   The present invention relates to a device for measuring the elasticity of the biological tissue.

2. Description of the Related Art

In the case of women, after the delivery of a child or in accordance with the aging, since the muscle suspend-

10   ing the urethra goes slacked and hence its elasticity deteriorates, there is a tendency that incontinence occurs even for slight shock or impact. To cope with this physical problem, an operation for restoring the elasticity of the muscle suspending the urethra is performed in such way

15   that suspension holes are provided in, for example, pelvis and the muscles around the urethra are suspended with the usage of the suspension holes. To perform an appropriate operation, it is necessary to evaluate an elasticity of the muscles that surround the urethra.

20   Since the urethra is located near the vagina, the evaluation of elasticity of the muscles surrounding the urethra can be conducted by measuring the elasticity of the biological tissue of an inner surface of a canal part of the vagina. However, since one of the functions of the

25   muscles surrounding the urethra is to enlarge and contract

the urethra with an appropriate elasticity, even if the conventional elasticity coefficient or factor for the biological tissue which is represented by the simple ratio of stress and distortion is used, it is impossible to suffi-

5　ciently evaluate its elasticity characteristics such as viscoelasticity. Since the diameter of the vagina is in the order of 15 mm, it is possible to insert a probe in the canal part thereof. However, in the prior art, there has been no appropriate probe and measuring method for

10　measuring the above elasticity of the muscles that surround the canal part of the vagina and suspend the urethra. Accordingly, the determination of the degree of elasticity deterioration of the muscle around the urethra and the degree of suspending the muscles upwardly using

15　the suspension holes for restoring the elasticity is still made through a diagnosis relied on experiences such as the palpation of the operator's fingers.

SUMMARY OF THE INVENTION

20　It is, therefore, an object of the present invention to overcome the above problems in the prior art.

It is another object of the present invention to provide an elasticity measuring device for biological tissue which is capable of quantitatively measuring the elastic-

25　ity of an inner portion of canal part of the biological

body.

According to one aspect of the invention, there is provided an elasticity measuring device for being inserted into a canal part of a human body and for measuring elas-

5   ticity of the inner side of the canal part of the human body, the device comprising:

a probe base for being inserted into the canal part of the human body;

a plurality of probes symmetrically arranged around

10   the probe base, which are located near the inner side of the canal part of the biological tissue when the device is inserted into the canal part and are driven to press onto and return from the biological tissue;

a plurality of resilient arm members each having one

15   end and the other end, the one end supporting thereon corresponding one of the plurality of probes and the other end being firmly fixed to the probe base;

a stress detection sensor provided on each of said probes, for detecting the hysteresis of the stress applied

20   to the biological tissue based on the repulsion from the biological tissue when said probes are driven to press onto and return from the biological tissue; and

a deviation detection sensor for detecting the hysteresis of changes in distance of said stress detection

25   sensor with respect to the probe base,

wherein the elasticity of the biological tissue is measured based on the hardness and deviation characteristics when the probes are driven to press onto and return from the biological tissue.

According to another aspect of the invention, there is also provided an elasticity measuring device for being inserted into a canal part of a human body and for measuring elasticity of the inner side of the canal part of the

5   biological tissue, the device comprising:

a probe base for being inserted into the canal part of the human body;

a plurality of probes symmetrically arranged around the probe base, which are located near the inner side of

10   the canal part of the biological tissue when the device is inserted into the canal part and are driven to press onto and return from the biological tissue;

a plurality of resilient arm members each having one end and the other end, the one end supporting thereon cor-

15   responding one of the plurality of probes and the other end being firmly fixed to the probe base;

a hardness sensor provided on each of the probes, for outputting a signal indicative of hardness of the biological tissue;

20   a hardness detection means for detecting the hardness of the biological tissue based on the signal from the hardness sensor; and

.a deviation detection sensor for detecting the deviation magnitude of the hardness sensor with respect to the

25   probe base,

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wherein the elasticity of the biological tissue is measured based on the hardness and deviation characteristics when the probes are driven to press onto and return from the biological tissue.

In the above elasticity measuring device of the invention, it is preferable that each of the probes comprises a balloon which is hydraulically expandable and contractable and is driven to press onto and return from
5   the biological tissue.

In the above elasticity measuring device of the invention, the hardness sensor comprises a vibration element and a vibration detection sensor. The hardness detection means comprises an input terminal connected to the vibra-
10   tion detection sensor; an output terminal connected to the vibration element; an amplifier having an input coupled to the input terminal; and a phase shift circuit connected between an output terminal of the amplifier and the output terminal, for changing a frequency and making a phase dif-
15   ference zero (0) when there occurs a phase difference between input waveforms applied to the vibration element and output waveforms forwarded from the vibration detection sensor. With the device having the above structure, while a resonant state of the closed loop circuit including the
20   hardness sensor and the biological tissue is maintained, hardness of the biological tissue is preferably detected by the frequency change caused by the change in hardness of the biological tissue.

The elasticity measuring device for the biological
25   tissue of the present invention comprises a probe base for

being inserted into the canal part of the human body, and
a plurality of probes symmetrically arranged around the
probe base, which are located near the inner side of the
canal part of the biological tissue when the device is

5   inserted into the canal part and are driven to press onto
and return from the biological tissue. The contact pres-
sure against the biological tissue, that is, the stress
when the probes are driven to press onto and return from
the biological tissue is detected by the stress detection

10   sensor as hysteresis. Also, the deviation magnitude of the
stress detection sensor with respect to the probe base,
that is, the deviation magnitude of expansion and contrac-
tion of the biological tissue is detected by the deviation
detection sensor as hysteresis. Based on these hysteresis

15   data, the hysteresis of the stress and deviation magnitude
characteristics of the biological tissue is evaluated and,
hence, the elasticity of the biological tissue, for exam-
ple, the viscoelasticity is measured and evaluated experi-
mentally and quantitatively.

20   The elasticity measuring device for the biological
tissue of the present invention comprises a probe base for
being inserted into the canal part of the human body, and
a plurality of probes symmetrically arranged around the
probe base, which are located near the inner side of the

25   canal part of the biological tissue when the device is

inserted into the canal part and are driven to press onto
and return from the biological tissue. The hardness of the
biological tissue when the probes are driven to press onto
and return from the biological tissue is detected as hys-

5   teresis by the hardness detection means based on the sig-
nal of the hardness sensor provided on the probe. Also,
the deviation magnitude of the hardness sensor with re-
spect to the probe base, that is, the deviation magnitude
of expansion and contraction of the biological tissue is

10 detected by the deviation detection sensor as hysteresis.
Based on these hysteresis data, the hysteresis of the
hardness and deviation magnitude characteristics of the
biological tissue can be evaluated. Since the hardness has
an intimate or close relationship to the elasticity coef-

15 ficient which is a ratio between the stress and distor-
tion, the elasticity of the biological tissue can be quan-
titatively measured based on analysis of the hysteresis.

The driving of the probes to press onto and return
from the biological tissue may well be achieved by the

20 balloon that is hydraulically expanded and contracted,
other than the plate spring and motor mechanism.

In one embodiment of the elasticity measuring device
of the invention, the device comprises a phase shift cir-
cuit which functions to change the frequency and make the

25 phase difference zero (0) when there occurs a phase dif-

ference between the input waveforms applied to the vibra-
tion element and the output waveforms detected by the vi-
bration detection sensor. With the device having the above
construction, while the resonance state of the closed loop
5 circuit including the hardness sensor and the biological
tissue is maintained, the hardness of the biological tis-
sue can be quantitatively detected based on the frequency
change caused by the change in hardness of the biological
tissue, whereby reliability of quantitative evaluation of
10 hardness hysteresis is highly enhanced.

BRIEF DESCRIPTION OF THE DRAWINGS

The above and other objects, features and advantages
of the present invention will be apparent from the follow-
15 ing description of preferred embodiments of the invention
explained with reference to the accompanying drawings, in
which:

Fig. 1 is a view showing an embodiment of the elas-
ticity measuring device of the invention in the state
20 wherein the device is inserted in the canal part of the
human body;

Fig. 2 is a view for explaining the movement of the
probe when the probe base and the sleeve arranged around
are moved relatively with each other in the longitudinal
25 axial direction;

Fig. 3 is a view showing another embodiment of the elasticity measuring device of the invention in which balloons are secured to the probe base as the probes;

Fig. 4 is a view showing the details of the foremost

5   end of the probe of the elasticity measuring device of the invention;

Fig. 5 is a graph showing the changes in the stress F (vertical line) and the deviation magnitude X (horizontal line) when the probes of the device of the invention are

10   driven to press onto and return from the desired measuring portion;

Fig. 6 is graphs showing exemplary measured elasticity characteristics when the measurements are conducted at different three points of the canal part of the human

15   body; and

Fig. 7 is a view showing a still further embodiment of the elasticity measuring device of the invention using a hardness detection device.

20   PREFERRED EMBODIMENTS OF THE INVENTION

Now, some preferred embodiments of the present invention are explained hereunder with reference to the accompanying drawings. Fig. 1 shows a state in which the elasticity measuring device 1 of the invention is inserted in

25   the canal part of the human body 3. The elasticity measur-

ing device 1 comprises a probe base 5 in the form of an

elongated bar having a few mm square or a few mm diameter

in section, and a probe 7 secured to the probe base 5, a

tip portion of which contacts the inner portion of the

5   canal part 3 of the biological tissue and which is driven

to press onto and return from the biological tissue to be

measured. To the outer surface of the probe base 5, there

is provided a sleeve 9 which has a slightly larger inner

diameter than the dimension of the outward form of the

10 probe base 5 and which is movable on the probe base 5 in

the elongated axial direction of the probe base 5.

The probe 7 includes a plurality of plate springs 15

which are symmetrically arranged at the outer periphery of

the probe base 5, a plurality of stress detection bases 17

15 correspondingly arranged at the foremost ends of the plate

springs 15, and a plurality of contact balls 19 made of

plastics in the form of substantial hemisphere. The probe

7 further includes a stress detection sensor 21 adhered to

each stress detection base 17. A pair of deviation detec-

20 tion sensors 23 are arranged in such a way that one ele-

ment is secured to the one side of the plate spring 15

whose side is opposite to the side where the stress detec-

tion base 17 is secured and the other element is secured

to a surface of the probe base 5 which surface is opposing

25 to the side where the one element is secured. The stress

detection sensor 21 and the deviation detection sensors 23

are connected to a stress calculation device 25 and a de-

viation calculation device 27, respectively, through cor-

responding signal lines. The outputs of both the stress

5   calculation device 25 and the deviation calculation device

27 are input to an elasticity calculation device 29. The

probes 7 are four (4) in number and are arranged around

the probe base 5 in a symmetrical relation. The symmetri-

cal relation of the probes 7 is important for the probe

10   base to keep a stationary state when the measuring device

is inserted in the canal part of the human body.

Fig. 2 is an illustration for explaining the movement

of the probe 7 when the probe base 5 and the sleeve 9 ar-

ranged around the probe base 5 are moved relatively with

15   each other in the longitudinal axial direction. When the

sleeve 9 is moved, for example, leftward in Fig. 2 with

respect to the probe base 5, the tubular inner side of the

sleeve 9 urges the plate spring 15 of the probe 7, and, in

the further advancement of the sleeve 9 in the leftward,

20   it functions to press the plate spring 15 against the

probe base side 5. Accordingly, a contact ball 19 arranged

at the foremost end of the probe 7 moves downward in the

drawings as the sleeve 9 moves in the leftward, whereas it

moves upward as the sleeve 9 moves in the rightward. In

25   this way, the contact ball 19 at the foremost end of the

probe 7 can be driven to press onto and return from the

biological tissue by the simple relative movement between

the sleeve 9 and the probe base 5. The relative movement

between the sleeve 9 and the probe base 5 can be achieved

5 by such small motor as a micro-motor (not shown in the

drawings). Further, in the case of a simple measurement,

such relative movement between the sleeve 9 and the probe

base 5 can be performed manually by the operator's hands

and fingers.

10   With the leftward movement of the sleeve 9, the probe

7 including the contact ball 19 can be entirely accommo-

dated within the sleeve 9. In this case, since the elas-

ticity measuring device 1 for the biological tissue can be

inserted to a desired portion of the biological tissue to

15 be measured in the state in which the probe 7 having the

complicated structure is fully accommodated within the

sleeve 9 being kept, the insertion of the device can be

effected smoothly. Thereafter, at the desired measuring

position after the insertion, the four probes 7 can be

20 opened and closed in an umbrella fashion by the movement

of the sleeve 9. The number of the probes is not limited

to four as in the above embodiment, and it may well be any

appropriate number, for example, one, two, three, six and

so on.

25   As the structure of the probe which is driven to

13

press onto and return from the biological tissue, other

than the above explained plate spring structure, a balloon

which is hydraulically expandable and contractable may

well be adopted. Fig. 3 shows such embodiment in which a

5   plurality of balloons 11 are secured to the probe base 5.

The balloon 11 is hydraulically communicated with a pump

13 and is driven to press onto and return from the bio-

logical tissue by the control of the output pressure of

the pump 13.

10   Fig. 4 shows in detail the foremost portion of the

probe 7 shown in Fig. 1. To the foremost end of the plate

spring 15, there is adhered the hemispherical contact ball

19 made of plastics having the stress detection base 17 on

the surface thereof opposing to the biological tissue. The

15   stress detection sensor 21 is arranged within the stress

detection base 17. The stress detection sensor 21 is a

distortion guage and is firmly adhered to the stress de-

tection base 17 using an adhesive agent. To the side of

the plate spring 15 whose side is an opposite side where

20   the reaction detection base 17 is arranged, there is pro-

vided a light receiving element. A light emitting element

opposing to the light receiving element is provided on the

surface of the probe base 5. The above pair of light emit-

ting and light receiving elements constitutes the devia-

25   tion detection sensor 23. The stress detection sensor 21

and the deviation detection sensor 23 are connected to the

stress calculation device 25 and the deviation calculation

device 27, respectively, by the respective signal lines.

Though the stress detection base 17 and the contact ball

5   19 are made of the same material, they may well be made of

different materials and may well be in a stacked configu-

ration. The deviation detection sensor, which is consti-

tuted by a pair of the light emitting and light receiving

element in the illustrated embodiment, may well be consti-

10   tuted by a combination of a magnet and a magnetic sensor,

for example, or other small contactless sensor.

Next, actual operation of the device having the above

structure will be explained hereunder. The probe base 5

with the four probes 7 arranged symmetrically around the

15   probe base 5 being closed in an umbrella fashion is in-

serted into the canal part of the human body, namely, the

vagina of the patient. Then, at the position where the

elasticity of the biological tissue is to be measured, the

probes 7 are opened by gradually moving the sleeve 9 rela-

20   tive to the probe base 5 in the rightward in Fig. 1. By so

doing, the contact ball 19 moves toward the biological

tissue side and urges to press against the biological tis-

sue of the canal part. Thereafter, the sleeve 9 is gradu-

ally moved or returned in the leftward with respect to the

25   probe base 5 so that the probes 7 are folded. The stress F

from the biological tissue at every moment when the probes

drive to press onto and return from the biological tissue

is detected by a pressure detection sensor 21 which is

arranged on the stress detection base 17 to which the con-

5   tact ball 19 is also provided. In the case where the pres-

sure detection sensor is a distortion guage, the detected

result as the variations in resistance is forwarded to the

stress calculation device 25 by a signal line and con-

verted to the corresponding stress after the necessary

10   calculation process.

The change in distance of the contact ball 19 with

respect to the probe base 5, that is, the relative varia-

tion occurring when the contact ball 19 is driven to press

onto and return from the biological tissue 3 is detected

15   by the deviation detection sensor 23. Specifically, as the

distance of the contact ball 19 with respect to the probe

base 5 changes, the distance between the paired light

emitting and receiving elements 23 changes accordingly.

The change in the amount of received light corresponding

20   to the change in the above distance is forwarded to the

deviation amount calculation device 27 through the signal

line and the magnitude of deviation is obtained thereat

after the necessary calculation process.

In this way, the stress F and the corresponding de-

25   viation magnitude X are obtained under the condition where

the probes are driven to press onto and return from the

biological tissue. The probe base 5 is positioned station-

ary at the desired measuring point of the biological tis-

sue after the insertion and, then, in the case of Fig. 1

5   illustration, the sleeve 9 is gradually moved in the

rightward with respect to the probe base 5 and then gradu-

ally moved to the leftward again. By so doing, the contact

ball 19 is first pressed against the biological tissue and

then returned therefrom. Specifically, by making the

10   stress F and the changes in the deviation magnitude X have

correlation, it is possible to analyze the hysteresis of

the elasticity of the biological tissue. Fig. 5 is an ex-

emplary graph which shows the changes in the stress F and

the deviation magnitude X of the biological tissue when

15   the probe 7 is driven to press onto and return from the

biological tissue at the desired measuring point. The ver-

tical line denotes the stress F and the horizontal line

denotes the deviation magnitude X. As shown in Fig. 5, as

a hysteresis curve of the elasticity of the biological

20   tissue can be obtained, it has been made possible to meas-

ure and evaluate the elasticity of the biological tissue

experimentally and quantitatively. The viscoelasticity of

the biological tissue can be quantitatively evaluated by,

for example, the size of area surrounded by the obtained

25   hysteresis curve.

Fig. 6 shows exemplary graphs of the elasticity when

the measurements are conducted at different three points

of the canal part of the human body. At the three points

A, B and C where the depth of the insertion of the probe

5 base 5 into the canal part of the human body are different

from one another, the probes 7 are driven to press onto

and return from the inner side of the canal part of the

human body, the hysteresis characteristics of the stress F

and the deviation magnitude X at that time are obtained

10 and illustrated for the purpose of comparison with the

stress F taken as the vertical line and the deviation mag-

nitude X taken as the horizontal line. For example, com-

paring the hysteresis characteristics at the point A with

those at the point B or C, since the area surrounded by

15 the hysteresis curve at the point A is smaller than the

area at the point B or C, it can be quantitatively evalu-

ated that the elasticity at the point A is greater than

the elasticity at the point B or C.

As has been explained hereinabove, it has been made

20 possible to measure and evaluate the elasticity of the

biological tissue by evaluating or analyzing the hystere-

sis characteristics between the stress and the distortion

based on the measurements of the stress and the distortion

of the biological tissue. On the other hand, since the

25 hardness has an intimate or close relationship to the

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elasticity coefficient which is a ratio between the stress
and the distortion, it is also possible to quantitatively
measure and evaluate the elasticity of the biological tis-
sue based on the hysteresis of the hardness.

5   Fig. 7 is a block diagram showing another embodiment
of the elasticity measuring device for the biological tis-
sue according to the invention, in which the hardness of
the biological tissue is measured. A hardness sensing de-
vice 41 includes a vibration element 43 and a vibration

10   detector 45 at the foremost end portion of the probe 7.
The vibration element 43 and the vibration detector 45 are
connected to an output terminal 47 and an input terminal
49, respectively, of a hardness detection means 51. The
hardness detection means 51 includes an amplifier 53 whose

15   input node is coupled to the input terminal 49, and a
phase shift circuit 55 connected between an output node of
the amplifier 53 and the output terminal 47. The phase
shift circuit 55 operates to change the frequency and make
the phase difference zero (0) when there occurs a phase

20   difference between the input waveforms applied to the vi-
bration element 43 and the output waveforms forwarded from
the vibration detector 45. The detail of such phase shift
circuit having the above functions is disclosed in the
Japanese Patent Application Kokai-Publication No. Hei 9-

25   145691 which should be incorporated by reference in this

application.

In the device having the above construction, while

the resonance state of the closed loop circuit including

the hardness sensor 41 and the biological tissue is main-

5   tained, the change in frequency caused by the change in

hardness of the biological tissue is detected by the fre-

quency deviation detection circuit 57 and, then, the de-

tected change is converted to the value of hardness by the

hardness converter 59. In this way, with the probe being

10   driven to press onto and return from the biological tis-

sue, hysteresis characteristics in relation to the hard-

ness of the biological tissue can be quantitatively meas-

ured and obtained.

With the elasticity measuring device for the biologi-

15   cal tissue according to the present invention, the elas-

ticity of the measured biological tissue can be quantita-

tively measured by simply inserting the canal part of the

human body with additional simple operation being fol-

lowed.

20   While the invention has been described in its pre-

ferred embodiments, it is to be understood that the words

which have been used are words of description rather than

limitation and that changes within the purview of the ap-

pended claims may be made without departing from the true

25   scope of the invention as defined by the claims.